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ABSTRACT

Students' own preconceptions are often resistant to change. According to researchers, conceptual conflict is an important factor in conceptual change; however, there is not enough evidence showing any relationship between cognitive conflict and conceptual change in the literature. This study aims to develop and validate the Cognitive Conflict Levels Test (CCLT) instrument which would: (1) measure cognitive conflict levels; (2) be capable of administering to elementary school students in a relatively short period of time; (3) be easily scored; and (4) require as little reading and writing as possible in a demonstration situation. In order to understand the levels of conflict, a model of cognitive conflict was formulated and features three stages: (1) preliminary stage; (2) conflict stage; and (3) resolution stage. (Contains 32 references.) (YDS)

The Development of an Instrument for the Measuring Students' Cognitive Conflict Levels.

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Introduction

Since the 1970's, science researchers have found that students begin lessons on most science contents with preconceptions that differ from scientific conceptions(Driver, Guesne, & Tiberghien, 1985; Pfundt & Duit, 1988/1994; Kwon & Oh, 1988; Kwon & Lee, 1993). These preconceptions often resist change. So many researchers insisted that it is not enough for science instruction simply to inform students of scientific conceptions. Students need to be convinced that the scientific conceptions are more intelligible, plausible and fruitful than their own conceptions (Posner, Strike, Hewon & Gertzog, 1982).

Recent researches in science education have proposed the cognitive conflict as an important factor for students' conceptual change. Some researchers have considered cognitive conflict as one of the conditions in conceptual change and proposed theoretical models for conceptual change (Posner et al., 1982; Hashweh, 1986; Kwon, 1989/1997). And many researchers have examined the effect of cognitive conflict experimentally (Hewson & Hewson, 1984; Thorley & Treagust, 1987; Niaz, 1995; Kwon & Kim, 1995; Druyan, 1997). Despite much enthusiasm for cognitive conflict strategy, some researchers suggested a careful approach to interpret the findings. Even when students are confronted with an anomalous situation, they are often unable to be at a meaningful conflict state or to become dissatisfied with their preconceptions(West & Pines, 1985; Hashweh, 1986; Champage, Gunston, & Kloper, 1985; Dreyfus, Jungwirth, & Eliovitch, 1990; Bodlakova, 1993; Elizabeth & Galloway, 1996; Dekkers & Thijs, 1998).

However, in these literatures, there were lack of evidences that the cognitive conflict was actually generated or how much the level of cognitive conflict is. But to have an adequate explanation of the relation between cognitive conflict and conceptual change, the existence and the levels of cognitive conflict should be identified anyway.

In recent research, various response characteristics of students who were in a cognitive conflict situation have been reported (Stavy & Berkovitz, 1980; Posner, Strike, Hewson and Gertzog, 1982; Hashweh, 1986; Lee, 1989; Drefus et al., 1990, Chinn & Breweral, 1993/1998, Chann, Burtis & Bereiter, 1997; Lee, 1998). Especially, Lee(1998) had rated the levels of cognitive conflict of the students by individual interviews. He used a pre-developed rating scale and showed the possibility of quantification of the level of cognitive conflict. But the interview method is time consuming and difficult to apply to a large number of subjects. In addition, this method also needs trained interviewers to insure consistent scoring. To overcome these troubles, it is necessary to develop a more simple but valid and reliable instrument for classroom testing. In this study, an instrument for the measurement of the Cognitive Conflict Levels Test (CCLT) was developed.

The problem of this study was to develop and validate an

instrument (CCLT) which would: (1) measure the cognitive conflict levels; (2) be capable of administration to classes of elementary school students in a relatively short period of time; (3) be easily scored; (4) require as little reading and writing as possible in a demonstration situation.

Procedures

Identification of the measurement components of cognitive conflict

The model of cognitive conflict process. To understand the levels of conflict, it is helpful to formulate a model of cognitive conflict process. Lee and kwon (in review) suggested a model of cognitive conflict process (see Figure 1). The theoretical foundation of the model was based on the analyses of literatures (Pondy, 1967; Spielberger, 1970; Stavy et al., 1980; Posner, Strike, Hewson and Gertzog, 1982; Hashweh, 1986; Kwon, 1989; Lee, 1990; Dreyfus, Jungwirth and Eliovitch, 1990, Chinn and brewer, 1993; Meyer and Carlisle, 1996; Joyce, 1997; Glynn and Muth, 1997; Chann, Burtis and Bereiter, 1997; Lee, 1998; Chinn and brewer, 1998). And the empirical foundation of the model was based on the analyses of protocols that were the responses of the students who were confronted with an anomalous situation. These protocols were generated by our researchers (Lee, 1989; Kwon and Kim, 1995; Lee, 1998).

This model has three stages: preliminary stage, conflict stage and resolution stage. The preliminary stage is the prior stage to cognitive conflict and includes the process of believing their preexisting conceptions and accepting the anomalous data (the experiment results) as genuine.

In this model, cognitive conflict is defined as a psychological state generated when one is confronted with an anomalous situation and the conflict stage is the period of the psychological state. This state is divided into three sub-stages: (1) recognition of anomalous situation, (2) interest or anxiety, (3) cognitive reappraisal of the situation.

For instance, one who is confronted with an anomalous situation and who recognized that the situation is incongruous with his/her conception would be interested in or be anxious about the situation then he/she would be reexamining his/her mental state. The researchers supposed that the stronger the psychological state is, the higher the levels of the cognitive conflict will be aroused. This model supposed four components in three sub-stages to be the psychological constructs of cognitive conflict.

In the resolution stage, one will try to resolve his/her conflict in any way and his/her trials will be expressed as a response behavior. The response behavior includes the responses suggested by Chinn and brewer (1998) such as ignoring, rejection, uncertainty, exclusion, abeyance, reinterpretation, peripheral theory change and theory change; and the knowledge-process activity suggested by Chann, Burtis and Bereiter (1997) such as sub-assimilation,

direct assimilation, surface-constructive, implicit knowledge building and explicit knowledge building.

And this model represented two assumptions as following: (1) the components of the conflict stage will be strongly correlated with the response behavior, (2) the student's metacognitive skill and motivation style will affect the process of cognitive conflict.

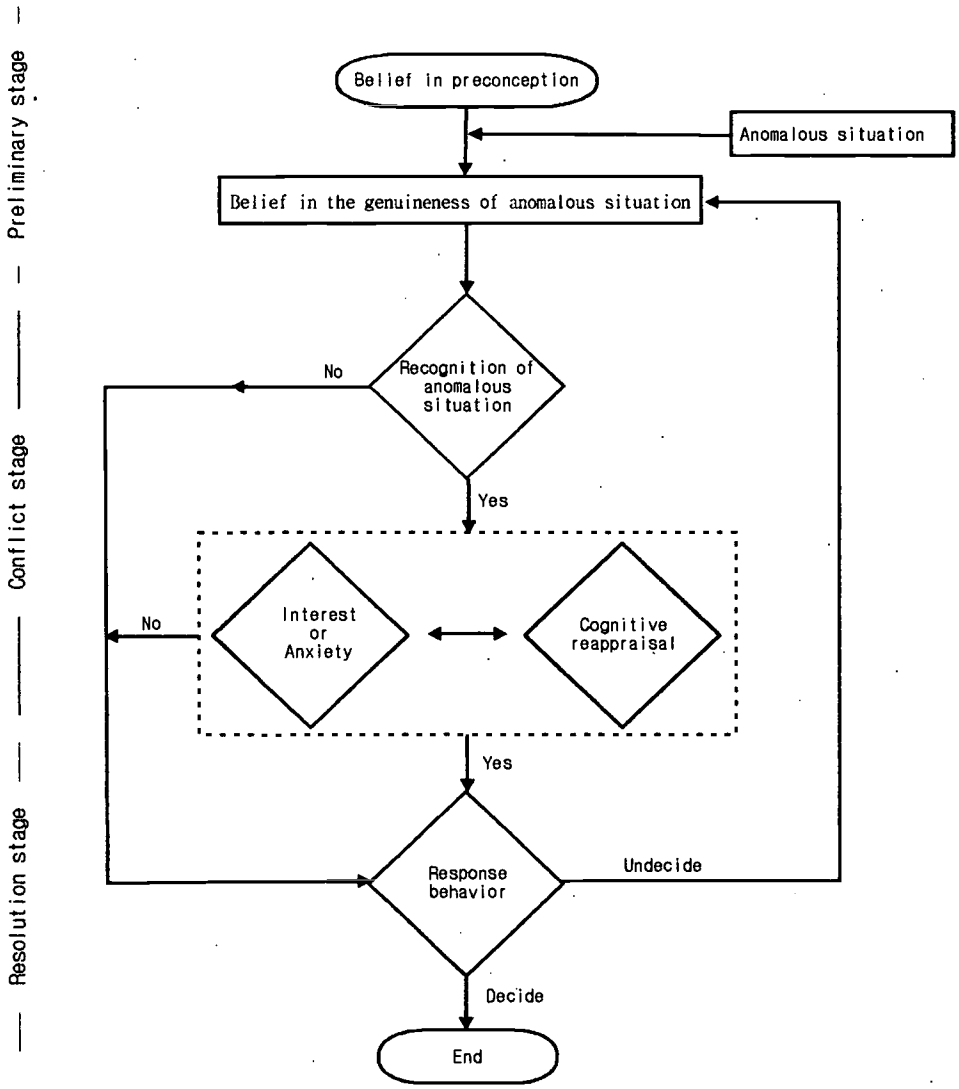


Figure 1. The model of cognitive conflict process (Lee & Kwon, in review)

Identification of the measurement components. From this model, we identified the measurement components of cognitive conflict as (1) recognition of anomalous situation, (2) interest, (3) anxiety, (4) cognitive reappraisal of the situation. Table 1 shows the operational definitions of the measurement components of cognitive conflict and the components in the preliminary stage.

Table 1

The operational definitions of the measurement components of cognitive conflict

Stage	Components	The operational definition
Preliminary -stage	Belief in preconception	Belief in understanding the problem, his/her choice and explanation by oneself (understanding the problem, his/her choice and explanation)
	Belief in the genuineness of anomalous situation	Belief in the observation, experiment equipment and experimenter (the observation, experiment equipment and experimenter)
Cognitive Conflict Stage	Recognition of contradiction	Recognizing one's conceptions is not inconsistent with the result of experiment (doubt, surprising, strange)
	Interest	being interested in anomalous situation (interest, curious, attention)
	Anxiety	Being anxious about anomalous situation (confused, agony, oppressed)
	Cognitive reappraisal of the situation	Reappraising his/her mental state aroused by the anomalous situation (suspending, think a little longer, seeking more a reasonable base)

In the preliminary stage, at first a student should have belief in his/her understand of the given problem. The understanding doesn't mean "correct" understanding of the problem. A student

who misunderstands the problem but believes his/her understanding is correct will receive a high score on belief of preconception. After observing the anomalous situation, a student should have belief in the genuineness of the situation. We supposed that this belief should be based on the student's judgement of the quality of the observation, experiment equipment and experimenter.

In the conflict stage, a student should recognize that one's conceptions are inconsistent with the result of the experiment. And he/she should have doubt, be surprised and think it strange. Then, the psychological state of the student will be exhibited such as being interested or anxious. These affective response will be determined according to the student's characteristics such as motivation style. A student being interested in this situation should show responses such as being interested, curious, attracting attention. But a student being anxious about this situation should show the responses such as being confused, being in agony and feeling oppressed.

Besides this, a student should reappraise his mental state to decide to suspend the state or not, to think a little longer or not and to seek more reasonable base or not. This cognitive reappraisal is similar to decision making and is one of the components that defines cognitive conflict.

Item selection

The constructs of cognitive conflict in the cognitive conflict process model were used as the basis for developing the instrument. At the beginning, 40 items were developed in accordance with the measurement components. Among them, we selected three items for each component. The selection rule of items was as following:

Does one statement represent one sub-test component?
Is there clear discriminating difference among statements?
Is the vocabulary in statements appropriate?

Final items are presented in table 2. All items were on a 5-point Likert scales (0 = not at all true of me, 5 = very true of me)

Table 2

Final items of Cognitive Conflict Levels Test (CCLT)

Measurement components		Test Items
Test Ⅰ (Belief in preconception)		1. I observed the picture well and understood the sentence.
		2. I think my choice is right.
		3. I have the reason for my choice.
TestⅡ (Belief in the genuineness of anomalous situation)		1. I observed the demonstration well.
		2. The equipment used for the demonstration has defects.
		3. If I do the demonstration again, I will get the same results.
Test Ⅲ	Recognition of contradiction	1. When I saw the result, I had a doubt about the reasons.
		2. When I saw the result, I was surprised at it.
		3. The difference between the result and my expectation made me felt strange.
	Interest	4. The result of experiment is interesting.
		5. Since I saw the result, I have been curious.
		6. The result of experiment attracts my attention.
	Anxiety	7. The result of the experiment confuses me.
		8. Since I can't solve the problem, I am in agony.
		9. As I can't understand the reason for the result, I feel oppressed.
	Cognitive reappraisal of the situation	10. I like to some more ascertain whether my idea is incorrect or not.
		11. I need to think about the reason for the result a little longer.
		12. I need to find a proper base of explaining the result.

Test Items for preconception

For the demonstration, two different problem situations were developed: one was a pulley problem and the other was electric bulbs in parallel.

Problem 1(A pulley)

There is a pulley with a tennis ball and a block of wood at each side. Figure 2 shows the apparatus. A ball is at the same level with the block. Then pull the block down so that the block is lower than the ball and "hold" it at this position. The problem is to ask students to guess the expected motion when the block is released(Watts & Zylbersztajn, 1981; Gunstone, 1986).

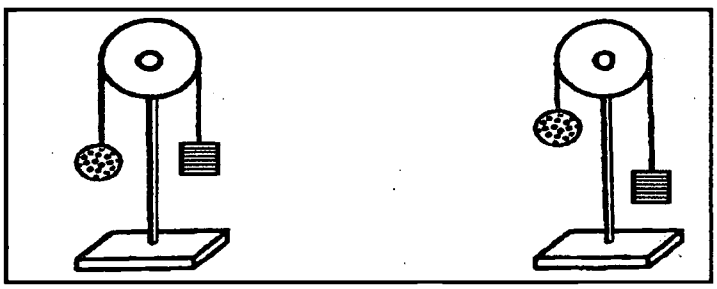
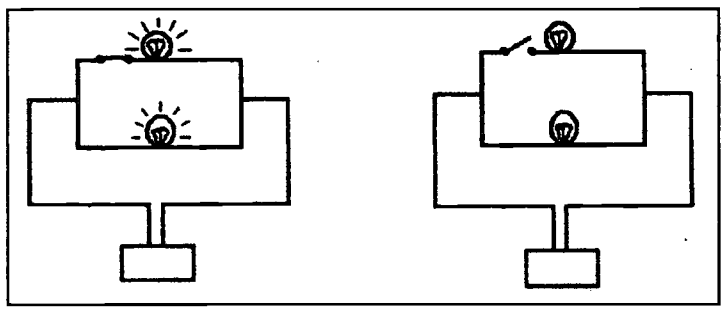


Figure 2. Pulley problem

We demonstrated the same situation presented right after students answered the problem.

Problem 2(electric bulbs in parallel)

Figure 3 shows a circuit of electric bulbs in parallel. There are two electric bulbs lighted up in parallel in the left figure. Then turn off the switch so that only one bulb is lighted up. The problem is to ask students to predict which bulb(A or B) is brighter than the other, after turning off the switch in the right figure(Dupin & Johsua, 1987).



A B

Figure 3. Electric bulbs in parallel Problem

We used two electric bulbs(30W-220V) and Styrofoam-board(60 ×70 ㎠) for the demonstration.

Test procedures

CCLT consists of the three tests shown in table3 below, and it requires a demonstration.

Table 3

Test procedures

Procedures	Purpose	Time (min)
Distribution		5
Test Ⅰ	Find students' preconception and their belief	7
Demonstration	Induce anomalous situation	2
TestⅡ	Belief in the genuineness of anomalous situation	1
TestⅢ	Test the cognitive conflict level	4
Withdrawal		1
Total		20

Participants practically spent 20 minutes to finish the CCLT. Teacher called student's attention not to go on to next page after

finishing test I. Students answered testII and testIII after the demonstration.

Pilot testing

Three pilot testings were conducted. The validity and reliability was observed to be improved test by test. After the second pilot tests, we could get quite satisfactory result in validity and reliability. Table 4 shows the results of pilot testings.

Table 4

The summary results of pilot testings

Pilot	First	Second	Third
Participants	88 elementary school students	125 elementary school students	305 elementary school students
Methods	-Content validity -Construct validity -Interview -Individual response analysis -Reliability	-Content validity -Construct validity -Interview -Reliability	-Content validity -Construct validity -Reliability
Revision & Complement	-Refinement of the questions (making the questions clear and checking the nuance of the statement etc.)	- Remove the space for writing the reason for the choices -Refinement of the questions (making the questions clear and checking the nuance of the statement etc.)	

In the first pilot test, six experts majoring in science education assessed content validity. 88 primary school students participated in the test and were asked to state their reasons for each answer. Students' responses were analyzed to assess their understanding of each question. The analysis found that some students had a biased interpretation or misunderstood the questions. These problems were revised and complemented. In the first pilot test, a blank space was used to record the reason for the student's answer. The purpose of the blank space was to examine whether the students understood the questions as intended and to find any biased responses through the answering process.

In the second pilot test, ten experts majoring in science education assessed content validity. And 125 primary school students participated in the test. A factor analysis of the responses was carried out and the reliability of the test was assessed by calculating cronbach-α . The questions were then restated to make then more clear and to represent the correct nuance. And after the second pilot test, we removed the blank space, because most students understood the question as intended in the interview test.

One month after the second pilot test, researchers conducted the final test. 305 primary students participated in the final tests. And we analyzed the validity and reliability of the tests. The result is showed in the following section.

Results

Validity of the Instrument

Content validity was assessed by six experts (two professors and four graduate students). They used a 5-stage Likert scale to judge the validity of each item. Content validity coefficients among the experts ranged from 0.85 to 0.97 and the mean value was 0.93.

Table 5 reports the correlations among the sub-tests and total score in the pulley problem situation. The correlations between the sub-tests and total score varied from 0.46 to 0.72, indicating a moderate to moderately high degree of association. Also, there were considerably stronger correlations among sub-tests in the same construct than between those sub-tests and sub-tests of other constructs. These correlations varied from 0.38 to 0.66.

Table 5
The correlations among the sub-tests and total score in the pulley problem situation

	Re1	Re2	Re3	In1	In2	In3	An1	An2	An3	Rea1	Rea2	Rea3
Re1	1.00											
Re2	.59**	1.00										
Re3	.38**	.40**	1.00									
In1	.41**	.40**	.14**	1.00								
In2	.53**	.51**	.28**	.52**	1.00							
In3	.51**	.50**	.27**	.49**	.65**	1.00						
An1	.10	.23**	.32**	.09	.16*	.13	1.00					
An2	.27**	.29**	.25**	.19**	.29**	.26**	.48**	1.00				
An3	.37**	.34**	.35**	.16*	.33**	.28**	.46**	.65**	1.00			
Rea1	.51**	.46**	.32**	.33**	.40**	.38**	.17*	.31**	.44**	1.00		
Rea2	.51**	.43**	.32**	.45**	.54**	.54**	.08	.24**	.35**	.59**	1.00	
Rea3	.39**	.29**	.211*	.41**	.39**	.44**	.12	.23**	.28**	.48**	.66**	1.00
Total	.71**	.70**	.56**	.58**	.72**	.69**	.45**	.60**	.67**	.70**	.72**	.62**

* p<0.05, ** p<0.01

Note. Re= Recognition, In= Interest, An= Anxiety, Rea= Reappraisal

Table 6 reports the correlations among the sub-tests and total score in the electric bulbs in parallel problem situation. The correlations between the sub-tests and total score varied from 0.43 to 0.69, indicating a moderate to moderately high degree of association. There are also moderately stronger correlations among sub-tests in the same construct than between the sub-tests of other constructs. These correlations varied from 0.28 to 0.66.

Table 6
The correlations among the sub-tests and total score in the electric bulbs in parallel problem

	Re1	Re2	Re3	In1	In2	In3	An1	An2	An3	Rea1	Rea2	Rea3
Re1	1.00											
Re2	.47**	1.00										
Re3	.28**	.38**	1.00									
In1	.22**	.28**	.12	1.00								
In2	.42**	.23**	.05	.55**	1.00							
In3	.37**	.30**	.14*	.42**	.66**	1.00						
An1	.11	.23**	.32**	.03	.03	.08	1.00					
An2	.31**	.27**	.31**	.09	.18*	.19**	.47**	1.00				
An3	.40**	.27**	.36**	.08	.19**	.22**	.43**	.53**	1.00			
Rea1	.37**	.30**	.31**	.28**	.35**	.36**	.22**	.33**	.37**	1.00		
Rea2	.31**	.14*	.13	.26**	.41**	.39**	-.01	.13	.31**	.48**	1.00	
Rea3	.35**	.20**	.09	.29**	.37**	.40**	.00	.15*	.23**	.45**	.48**	1.00
Total	.66**	.58**	.52**	.49**	.61**	.63**	.43**	.59**	.65**	.69**	.56**	.56**

* p<0.05, ** p<0.01

Note. Re= Recognition, In= Interest, An= Anxiety, Rea= Reappraisal

Factor analysis

The 12 sub-tests in the CCLT were subject to a factor analysis, commencing with the principal component analysis and extent of communality, and then computation of a rotated factor matrix by assigning four factors. Table 7 shows the result of the factor analysis of CCLT in the pulley problems situation. The analysis found that three sub-tests of interest were loaded on the first factor, three sub-tests of reappraisal on the second factor, three sub-tests of anxiety on the third factor and three sub-tests of recognition on the fourth factor. These four factors completely coincided with the four measurement components proposed as the constructs of cognitive conflict and explained 74.50% of the total variance, indicating a moderately high degree of association.

Table 7
Rotated Component Matrix(a), Pulley problem situation

	Component			
	1	2	3	4
Interest1	.780	.216	.049	-.056
Interest2	.769	.223	.161	.216
Interest3	.746	.250	.110	.207
Reappraisal3	.263	.813	.098	-.016
Reappraisal2	.391	.758	.044	.204
Reappraisal1	.153	.705	.175	.355
Anxiety2	.165	.141	.841	.048
Anxiety1	.050	-.077	.797	.137
Anxiety3	.089	.296	.751	.250
Recognition3	-.003	.120	.242	.807
Recognition2	.518	.125	.159	.615
Recognition1	.447	.348	.066	.561

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

In another situation(electric bulbs in parallel), 12 sub-tests in CCLT were subject to a factor analysis, commencing with the principal component analysis and extent of communality, and then computation of a rotated factor matrix by assigning four factors. Table 8 shows the result of the factor analysis of CCLT in the electric bulb in parallel problem situation. The outcome was that three sub-tests(reappraisal 1, 2, 3) loaded on the first factor. The second factor included three sub-tests(interest 1, 2, 3). The third factor included three sub-tests(anxiety 1, 2, 3). The fourth factor included three sub-tests(recognition 1, 2, 3). These four factors completely coincided with the four measurement components that were presupposed to be the constructs of cognitive conflict. Similar to the results of table 7, these results explained 69.75% of the total variance, indicating a moderately high degree of association.

Table 8
Rotated Component Matrix(a), Electric bulbs in parallel problem

	Component			
	1	2	3	4
Reappraisal2	.81	.21	.03	.01
Reappraisal3	.75	.24	-.01	.09
Reappraisal1	.65	.17	.29	.25
Interest2	.30	.84	.06	.04
Interest1	.06	.74	-.05	.15
Interest3	.32	.73	.10	.13
Anxiety1	-.13	.04	.83	.11
Anxiety2	.13	.10	.80	.16
Anxiety3	.38	-.09	.68	.24
Recognition2	.02	.26	.11	.82
Recognition3	.08	-.08	.33	.68
Recognition1	.38	.26	.11	.60

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Reliability of the Instrument

Reliability of the test was assessed by calculating internal consistency values using Cronbach's alpha. Table 9 shows the values determined for each sub-test as well as for the total test.

Table 9

Reliability of the Instrument

Test items / Problems	Sub-test				Total test
	Recognition	Interest	Anxiety	Reappraisal	
Pulley (Cronbach-α)	.6915	.7743	.7685	.7880	.8606
Electric bulbs in parallel (Cronbach-α)	.6257	.7957	.7109	.7067	.8182

The final instrument showed moderate reliability in sub-test(cronbach-α .62~ .79) and in total test(cronbach-α .81 ~ .86).

Conclusions

The researchers identified four measurement components of cognitive conflict and developed test items for each component. Through a process of development and revision in two pilot tests, the final instrument(CCLT) was supported as a reliable and valid instrument to measure the cognitive conflict levels. The efficiency and convenience of use through paper-pencil administration with no need for individual interviews or demonstrations was backed up with a reliability which was considered to be satisfying. All the items appeared to be functioning to discriminate among the various levels of cognitive conflict.

The validity of CCLT was also supported by the result of factor analysis. The principal component method was used with rotation by assigning four factors. As the result, four main factors completely coincided with the four components that were presupposed to be constructs of cognitive conflict.

The construct validity of the measurement was measured on the basis of the assessment by six experts(two professors and four graduate students). Content validity coefficients among experts ranged from .85 to .97 and the mean value was .93.

Significance

To measure students' levels of cognitive conflict, researchers have been using an interview method. This method is time consuming and difficult to secure high reliability. However, since the CCLT developed in this study is a paper-and-pencil test, it can be applied to a large group of students with in a single class period. Teachers can use the results to better understand the process of conceptual change of their students and to match instruction and materials accordingly.

Researchers can use the CCLT to measure the cognitive conflict levels of students and with this instrument, many candidate variables which might affect cognitive conflict and/or conceptual change can be tested very conveniently. Therefore, the CCLT can be useful in research about the relationship among the variables of learner, knowledge building, conceptual change and the levels of cognitive conflict.

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